Chapter 1

Small Mammal Inventories in the East and West Usambara Mountains, Tanzania. 1. Study Areas, Methodologies, and General Results

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Abstract

The Eastern Arc Mountains of southeastern Kenya and Tanzania hold a rich and unique biodiversity. The most celebrated of these mountains are the East and West Usambaras. Although these massifs have been the subjects of biological study for over a century, little is known about the shrews, bats, and rodents occurring in the montane forests. Using pitfall buckets, small mammal traps, and mist-nets, between 1991 and 1993, we surveyed the small mammals in the Amani area in the East Usambara and Ambangulu area in the West Usambara to document the natural history of the local fauna. These surveys were conducted during the dry season annually between early July and early September.

In this chapter, we outline the study sites, methodologies, capture rates, and other trapping details. A total of 18,563 sample-nights was accrued over the three-year study, and on these two massifs, we documented 12 crocidurine shrew, one macroscelidid elephant shrew, 19 bat, and 14 rodent species. Species accumulation curves suggest that additional trapping effort may be required in the East Usambara Mountains to have a more complete view of the local small mammal fauna. There was no significant difference in the number of individuals captured or measures of species diversity in the pitfall and trap lines that were installed in the same location during the course of this study, suggesting that repeated sampling did not negatively affect the small mammal fauna of the study areas.

Introduction

The Eastern Arc Mountains (EAM), which extend from southern Kenya to southern Tanzania, have been the focus of field and systematic studies by biologists because of their extraordinary levels of endemism and diversity. Over the past century, workers have studied the flora and fauna of the 12 separate massifs or "montane islands" making up the archipelago. Biota studied include bryophytes (e.g., Pócs, 1975, 1985), angiosperms (e.g., Lovett et al., 1988; Lovett, 1990; Iversen, 1991; Cordeiro & Howe, 2003), invertebrates (e.g., Griswold, 1991; Hoffman, 1993), reptiles and amphibians (e.g., Loveridge, 1935, 1937; Menegon et al., 2008), birds (e.g., Stuart, 1983; Newmark, 1991, 2006; Cordeiro, 1998a; Lens et al., 2002), small mammals (e.g., Hutterer, 1986; Carleton & Stanley, 2005; Makundi et al., 2006; Stanley & Hutterer, 2007), and larger mammals such as primates (Davenport et al., 2006; Perkin, 2007; Rovero et al., 2009), carnivores (De Luca & Mpunga, 2005), and duikers (Rovero et al., 2005).

The Usambara Mountains in northeastern Tanzania, composed of separate eastern and western massifs, were among the first EAM studied and, as a result, are probably the best known of the archipelago. The village of Amani at about 900 m elevation in the East Usambara became in late 1800s the seasonal capitol of the German colonial government, bringing the area to the attention of naturalists, at least in part, with the installation of access roads and other infrastructure (Conte, 2004). The East African Agricultural Research Station and the National Institute for Malaria Research, both in Amani, attracted a number of active field biologists, including Reginald E. Moreau, who documented the unique diversity of the area, with a focus on the forest-dwelling avifauna (Moreau, 1935). Although the forests in the Amani region have been under study for many years, little is known about certain biotic groups. This is particularly important in light of the local habitat alteration due to historical introduction of coffee (*Coffea arabica*) and tea (*Camellia sinensis*) plantations and small-scale agriculture over the last two centuries (Newmark, 2002) (Figs. 1 and 2). The discovery of gold in streams near Amani in 2003 has also caused a significant increase in human pressure on the forests over the last decade (Newmark, 2004).

The unusually high level of endemism exhibited by other biotic groups in the Usambara Mountains (Rodgers & Homewood, 1982), overlaid on largely datable patterns of natural forest fragmentation, prompted our study of the local small mammals. Between 1991 and 1993, we conducted three annual surveys of the small mammals (shrews, bats, rodents, and elephant shrews) in select forests of the East and West Usambara Mountains. The initial motivation for the surveys was to study the effect of forest fragmentation on small mammals using Newmark's (1991) research at the same sites on understory birds as the point of departure. Within this

FIG. 1. Tea plantations and forest on the Monga Tea Estate, East Usambara Mountains, Tanzania. Tea is planted in areas that were cleared of natural forest. Photo by W. T. Stanley.

FIG. 2. Agricultural area in the East Usambara Mountains resulting from human alteration of historically forested habitats. Note both tea plantation and areas cultivated for subsistence crops. Photo by W. D. Newmark.

chapter, we give details on previous small mammal studies conducted in the East and West Usambara Mountains, our study sites, sampling methodologies, and general results.

Previous Work

Given that Amani in the East Usambara and Lushoto in the West Usambara Mountains were administrative centers for the German colonial government of Tanganyika, the biological diversity of the surrounding forests has long been the subject of natural history studies (Rodgers & Homewood, 1982). Such investigations include those of Engler (1893, 1894) on plants, Barbour and Loveridge (1928) on terrestrial vertebrates, and Moreau (1935, 1952) on birds. The establishment of research stations focused on economic botany and disease vectors affecting humans attracted biologists to these massifs (Rodgers, 1998; Conte, 2004). In particular, the study of small mammal ectoparasites and their influence on human health has been on-going since the 1960s (e.g., Hubbard, 1972; Kilonzo et al., 1992, 2006).

Moreau (1935), in particular, highlighted the importance of the Usambaras as a center of biological diversity. Rodgers and Homewood (1982) summarized available information and presented faunal lists of various groups, including small mammals. Newmark (1991, 2006) and Newmark et al. (2010) studied the effects of forest fragmentation and disturbance on understory birds in the East and West Usambara Mountains. Although some taxonomic and plague vector studies previously focused on Usambara small mammals (e.g., Hutterer, 1986; Kilonzo et al., 1992), no intensive survey of shrews or rodents was conducted until the early 1990s, when this study was initiated. The organization Frontier-Tanzania (http://www.frontier.ac.uk/) conducted a series of faunal inventories, primarily in the East Usambara; the results are presented in technical reports (see Howard, 1996).

Conservation Actions in the East and West Usambara Mountains

Conservation efforts in the Usambaras were initiated more than a century ago under German colonial rule (Conte, 2004) and have increased in recent years. Reasons for conservation efforts include the importance of the Usambara forests as water catchments, the exceptional level of endemism among the plants and animals, and the historic human-induced habitat alteration, some of which started 2000 years ago in the Early Iron Age (Schmidt, 1989). The German administrators of Tanganyika, who recognized the value of the montane forests in northern Tanzania, including the East and West Usambaras, initiated the first documented large-scale conservation project. As a result, several forest reserves were established to protect water catchments, but also timber stands for later use by the colonial government (Rodgers, 1998). At the same time, the German colonialists created large agricultural estates in both the East and West Usambaras (Hamilton & Mwasha, 1989a; Conte, 2004).

After transitioning to British rule in 1916, a Forest Department was created in 1921 to expand timber exploitation. This new administration appreciated the importance of the local forests for soil and water conservation and created laws to reduce large-scale clearing of forests on private estates (Hamilton & Mwasha, 1989b). After Tanzania's independence in 1961, some reserves were partially de-gazetted and became sites for local agriculture, and the pressure on remaining forests increased dramatically (Hamilton & Mwasha, 1989c), as did calls for conservation of various natural habitats of the East and West Usambara Mountains (Redhead, 1981; Rodgers & Homewood, 1982). Many of the reviews summarizing the threats facing the forests of the Usambara Mountains list the critical need for biotic inventories to assist in developing conservation strategies (Rodgers & Homewood, 1982; Howell, 1989; Goodman et al., 1995).

Study Area

The East and West Usambara Mountains are within the Tanga Region administrative zone and separated by the Lwengera Valley, which descends to 300 m (Figs. 3–5). The West Usambara massif extends from approximately 4°28′ to 5°6′S and 38°10′ to 38°40′E. The East Usambara massif occurs from about 4°46′ to 5°13′S and 38°32′ to 38°50′E. This

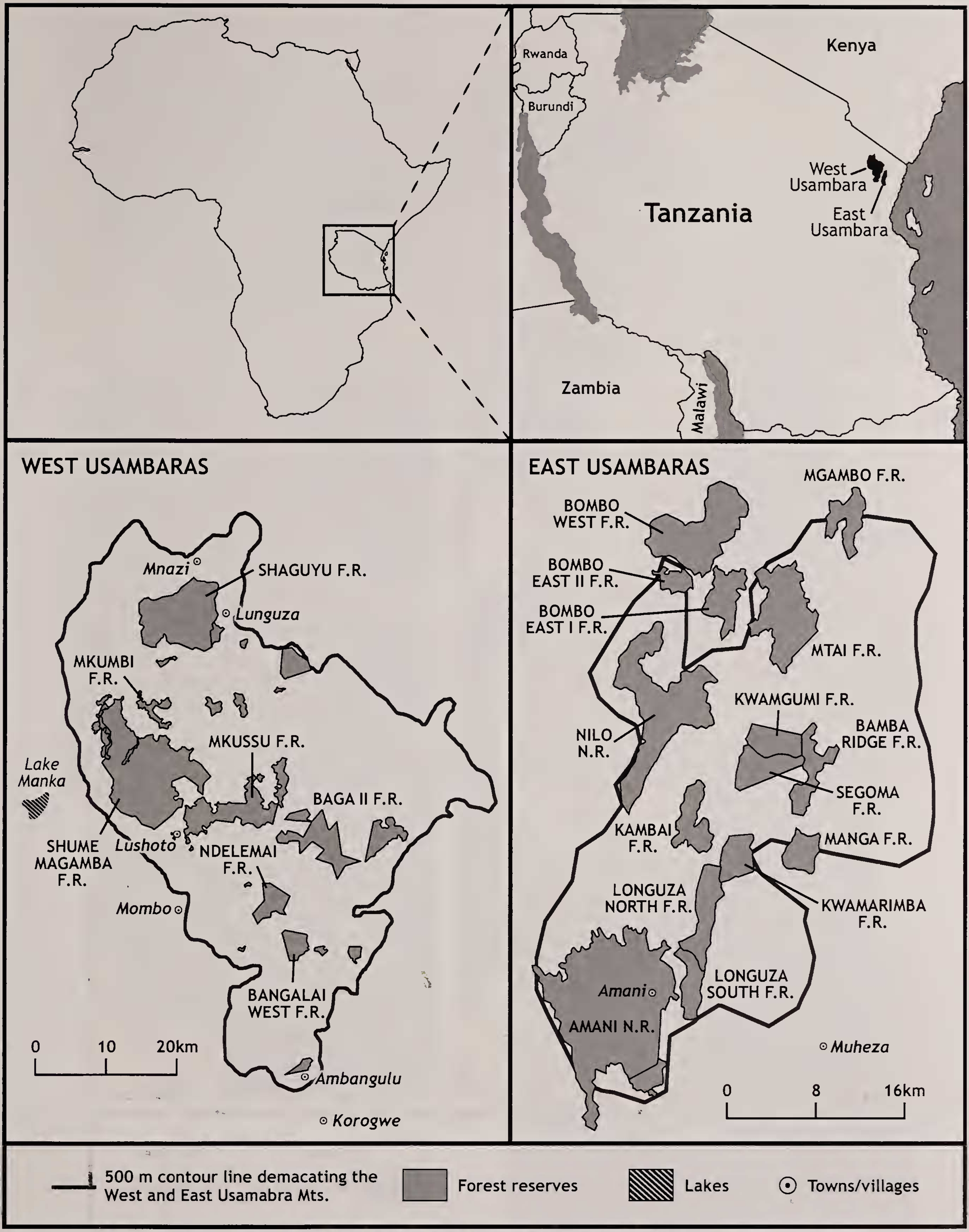

FIG. 3. General map of the East and West Usambara Mountains.

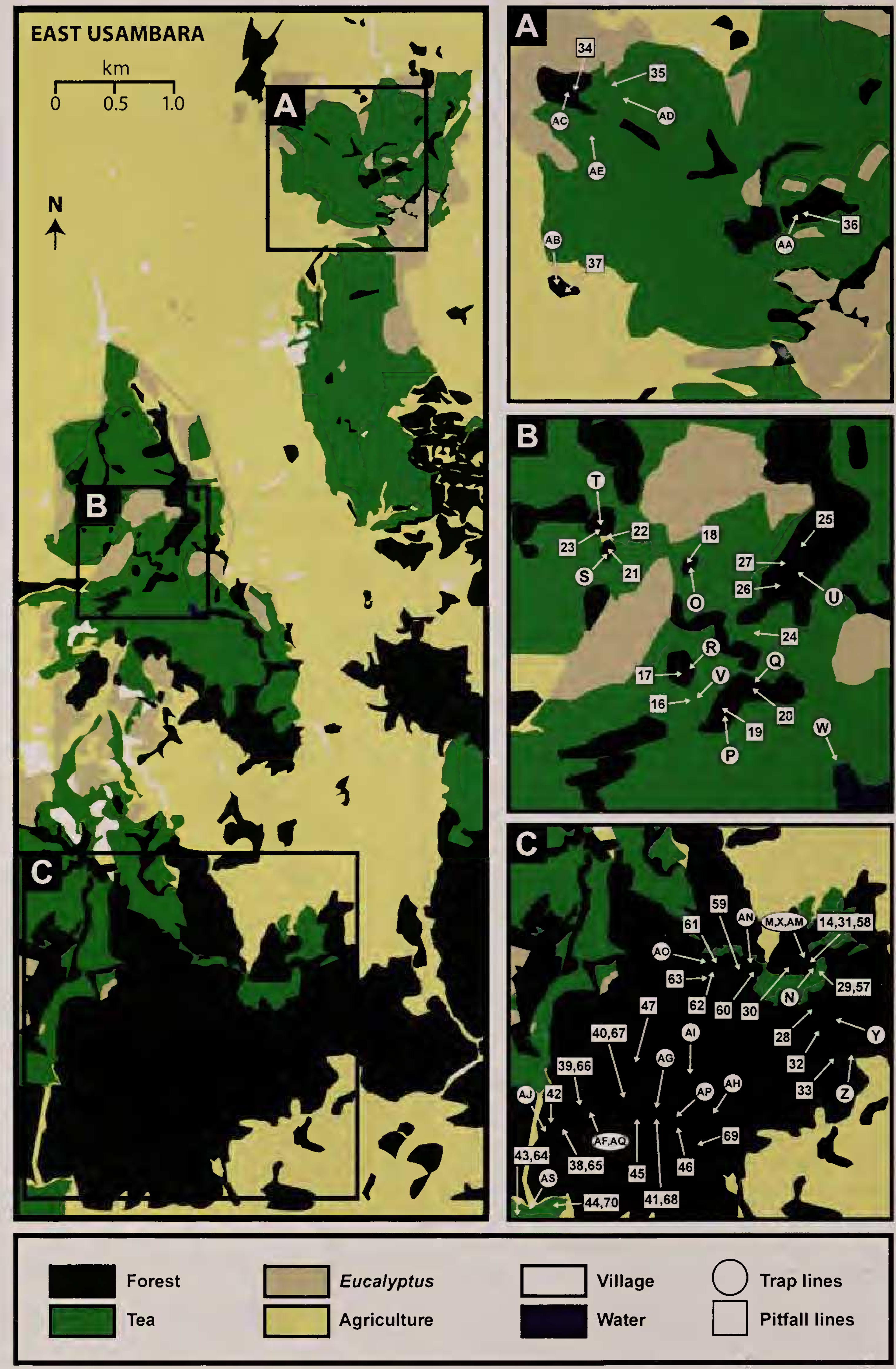

FIG. 4. Map of East Usambara study sites. Numbered circles refer to specific trap lines, and numbered squares refer to specific pitfall lines (see Tables 4 and 5).

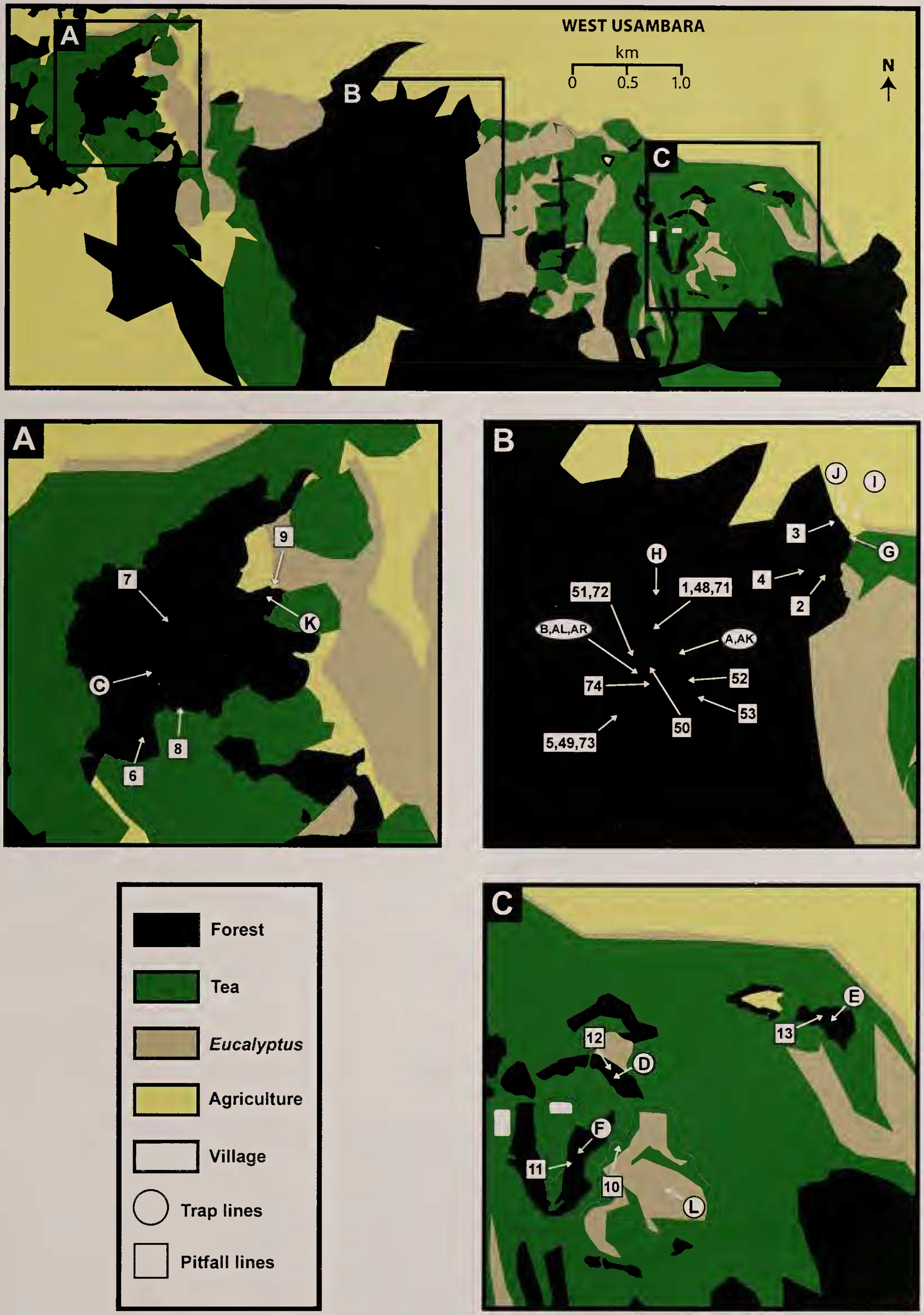

FIG. 5. Map of West Usambara study sites. Numbered circles refer to specific trap lines, and numbered squares refer to specific pitfall lines (see Tables 4 and 5).

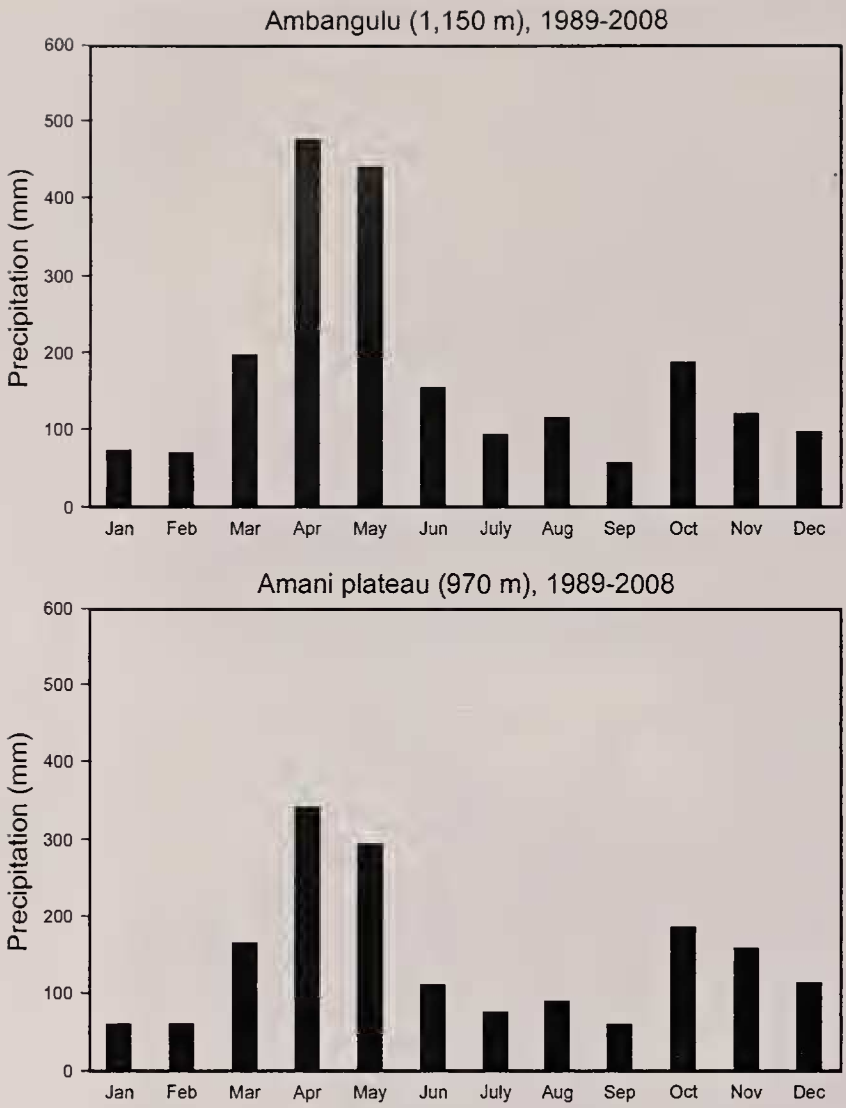

FIG. 6. Mean monthly precipitation between 1989 and 2008 at (**A**) 1150 m elevation at Ambangulu, West Usambara Mountains, and at (**B**) 970 m elevation at Marikitanda on the Amani Plateau, East Usambara Mountains.

study was conducted between 1991 and 1993 during the dry season. Natural forest, tree plantations, and non-forested matrix habitats comprising mostly tea or a combination of tea, *Eucalyptus,* and agricultural land were sampled on the Bulwa, Kwamkoro, and Monga Tea Estates and the Amani Nature Reserve in the East Usambara and on the Ambangulu Tea Estate in the West Usambara. Survey dates in the East Usambara were: 5–9 August 1991, 19 July–24 August 1992, and 30 July–13 August 1993. The Ambangulu Tea Estate forests in the West Usambara were sampled 1–31 July 1991, 27 August–4 September 1992, and 18–22 August 1993.

Moreau (1935) summarized the rainfall pattern across the East and West Usambara Mountains, based on records from regional meteorological stations, and found that areas near Amani in the East Usambara received the highest annual rainfall. Maximum annual rainfall in the West Usambara is along the southeastern edge of the massif. Based on long-term precipitation records recorded by the Marikitanda Tea Research Station (970 m) on the Amani Plateau in the East Usambara and the Ambangulu Tea Estate (1150 m) in the West Usambara, mean annual precipitation between 1989 and 2008 in the East Usambara was 1717 mm compared with 2056 mm in the West Usambara. Patterns of mean monthly precipitation over this period were very similar between the two weather stations (Fig. 6), although Ambangulu received on average 30% more precipitation during the "long rains" between March and June than Marikitanda. On the Amani Plateau, mean monthly temperatures recorded at 911 m from 1941 to 1970 ranged from 16.3°C to 24.8°C (Rodgers & Homewood, 1982). Although long-term temperature data are not available from Ambangulu, the simultaneous recording of air temperature at two-hour intervals in the control sites (see below) at Ambangulu and Amani over a 229-day period between November 1997 and July 1998 revealed that mean daily temperature is 1.6°C cooler at Ambangulu at 1250 m than at Amani at 977 m (Newmark, 2005). Thus, our study zone in the West Usambara is wetter and cooler than that of the East Usambara.

Sampling Sites

Details on forest sites, specific localities, sampling dates, and effort are listed in Tables 1 through 5, and mapped in Figures 4 and 5. The forested sites are fragments of

TABLE 1. Forest fragments sampled in the East and West Usambara Mountains between 1991 and 1993. Area (ha), W.D.N. study site(s) ID number, latitude and longitude coordinates, and elevation are presented for each study site. For further reference, site names used in the field notes of W.T.S. and S.M.G., as well as references to each fragment name as presented by Newmark (1991), are listed.

Forest fragment location	Area (ha)	W.D.N. site ID number	Coordinates	Elevation (m)	Site ID name in W.T.S./S.M.G. field notes	Fragment label in Newmark (1991)
East Usambara						
Bulwa fragments	2.6	5	5°1′37.78″S, 38°37′2.39″E	1042	2.7	1
	3.1	4	5°1′45.58″S, 38°37′27.49″E	972	1.6	2
	0.4	6	5°2′10.82″S, 38°36′48.38″E	982	0.38	3
Monga fragments	0.2A	9	5°3′33.78″S, 38°36′12.7″E	1136	0.1	4
	0.2B	13	5°3′28.63″S, 38°36′3.03″E	1137	0.42	5
	0.8	14	5°3′34.3″S, 38°36′3.18″E	1125	0.8	6
	29.4	10, 11, 12	5°3′25.34″S, 38°36′18.1″E	1057	30	7
	0.6	8	5°3′43.75″S, 38°36′10.23″E	1150	0.45	8
	3.3	7	5°3′47.69″S, 38°36′14.38″E	1141	9.4	9
Amani Nature Reserve	521	3, 16, 17	5°6′21.43″S, 38°35′52.07″E; 5°5′41.19″S, 38°37′7.32″E	1057	EU Control	10
West Usambara						
Ambangulu	886	22, 23	5°4′0.45″S, 38°24′37.71″E	1297	WU Control	
	37.8	21	5°3′40.1″S, 38°23′163″E	1215	40	
	5.5	18	5°4′20.41″S, 38°25′44.59″E	1179	2.4	
	1.9	20	5°3′57.59″S, 38°26′2.73″E	1171	1.8	
	1.5	19	5°4′3.54″S, 38°25′49.28″E	1191	0.8	

TABLE 2. Sampling effort across all three years for both the East and West Usambara Mountains. Sample-nights represent the sum of bucket-nights and trap-nights.

	1991			1992			1993			Total		
Massif	Bucket-nights	Trap-nights	Sample-nights	Bucket-nights	Trap-nights	Sample-nights	Bucket-nights	Trap-nights	Sample-nights	Bucket-nights	Trap-nights	Sample-nights
East Usambara	66	410	476	2335	5917	8252	913	1698	2611	3314	8025	11,339
West Usambara	1058	4155	5213	607	905	1512	259	240	499	1924	5300	7224
Total	1124	4565	5689	2942	6822	9764	1172	1938	3110	5238	13,325	18,563

historically contiguous forest and were the same ones studied by W.D.N. (Newmark, 1991, 2006). In the East Usambara, 10 forest fragments were sampled, as well as non-forested habitats including tea, *Eucalyptus* plantations, and fallow agricultural land. Nine of these fragments were less than 30 ha; three were on the Bulwa Tea Estate, five were on the Monga Tea Estate, and one was on the Amani Nature Reserve. The smaller forest fragments ranged in size from 0.2 to 29.4 ha, whereas the biggest was 521 ha (Fig. 4). In the West Usambara, five forest fragments were sampled, including four smaller forest fragments ranging in size from 1.5 to 38.4 ha and a larger area that was 887 ha (Fig. 5). In this and subsequent chapters in this volume on mammals (Stanley & Goodman, this volume a,b; Stanley et al., this volume), we refer to each smaller fragment by its size (i.e., 29.4-ha fragment) and to the control sites in the East and West Usambara Mountains as the EU control site and WU control site, respectively. In the EU control site, the northeastern and southwestern portions were sampled during our small mammal surveys.

Field Methodology

PITFALL LINES—Small mammals were sampled using a variety of techniques. Pitfall lines were intended principally to capture shrews and, in most cases, were placed on narrow (<50 cm) trails cut for their installation. Each pitfall line consisted of 11 buckets, set 5 m apart, and buried in the ground with the top of the bucket flush with the ground. Each bucket was 26 cm high, with an upper diameter of 26 cm, a lower diameter of 24 cm, and a 15-liter capacity. The bottoms of the buckets were pierced with small holes to allow water drainage. Each line had a 50 cm-high opaque black plastic drift fence running over the center of each bucket (Fig. 7). These passive and non-baited traps capture animals moving on the forest floor that encounter the drift fence and follow it until they fall into a bucket. The pitfall lines were generally set along straight trails; however, rocks and logs occasionally forced deviations. For further details on this technique, see Stanley et al. (1996) and Voss and Emmons (1996). Pitfall lines were checked twice per day, in the early morning and mid-afternoon. A "bucket-night" refers to one bucket in operation for a 24-hour period (0700 to 0700 h). Table 4 lists each line with placement details.

TRAP LINES—Trap lines consisted of three different types of traps: Museum Specials, 14 × 7 cm; Victor Rat Traps (referred to as Victor Trap throughout this volume), 17.5 × 8.5 cm; and

TABLE 3. Sampling effort across all three years for both the East and West Usambara Mountains broken down by fragments and habitat types. Sample-nights represent the sum of bucket-nights and trap-nights.

	Bucket-nights	Trap-nights	Sample-nights
Forest habitats on each massif			
East Usambara			
Control site	1793	5690	7483
Fragments	792	2305	3097
West Usambara			
Control site	1397	2122	3519
Fragments	450	1560	2010
Non-forest habitats on both massifs			
Tea	575	1003	1578
Agriculture	154	470	624
Eucalyptus	77	175	252
Total	5238	13,325	18,563

FIG. 7. A section of a pitfall line utilized to catch shrews and small rodents. Note the plastic fence running transversely across the top of a bucket buried in the soil. Photo by W. T. Stanley.

TABLE 4. Summary of pitfall lines installed at different sites in the East and West Usambara Mountains between 1991 and 1993. Pitfall lines are listed by name (used in W.T.S. and S.M.G. field notes) in the first column, together with any lines that were set in the exact same location in other years. Also presented are the dates each pitfall line was in place and habitat type (F = forest, D = disturbed forest, A = agricultural land, T = tea) and site for habitats of forest and disturbed forest (see Table 1). Overall pitfall success includes both rodent and shrew captures.

Pitfall line/subsequent lines in same location	Dates and habitat (site)	No. of buckets/ bucket-nights	No. of species/no. of individuals (overall trap success [%])	No. of shrew species/no. of shrews (shrew trap success [%])	Coordinates
West Usambaras					
1991					
1/48, 71	1–10 Jul F (control)	12/108	3/10 (9.3)	3/10 (9.3)	5°40′3.22″S, 38°24′40.32″E
2	2–10 Jul F (control)	12/89	2/2 (2.2)	2/2 (2.2)	5°3′46.64″S, 38°24′42.54″E
3	5–13 Jul F (control)	11/88	3/4 (4.5)	2/3 (3.4)	5°3′38.56″S, 38°24′44.40″E
4	6–15 Jul F (control)	11/99	1/1 (1.0)	0	5°3′44.38″S, 38°24′40.57″E
5/49, 73	10–17 Jul F (control)	21/147	3/13 (8.8)	3/13 (8.8)	5°4′02.63″S, 38°24′37.24″E
6	17–24 Jul F (control)	11/77	0	0	5°3′40.41″S, 38°22′54.56″E
7	18–24 Jul F (control)	11/66	1/1 (1.5)	1/1 (1.5)	5°3′28.45″S, 38°22′59.89″E
8	20–24 Jul F/T (control)	8/32	2/2 (6.3)	2/2 (6.3)	5°3′37.95″S, 38°22′57.60″E
9	20–24 Jul D (control)	11/44	0	0	5°3′27.42″S, 38°23′13.57″E
10	13–17 Jul D (control)	11/77	4/7 (9.1)	2/5 (6.5)	5°4′22.99″S, 38°25′48.93″E
11	25 Jul–1Aug F (5.5)	11/77	0	0	5°4′20.85″S, 38°25′44.59″E
12	25 Jul–1Aug F (1.5)	11/77	1/1 (1.3)	1/1 (1.3)	5°4′08.54″S, 38°25′49.37″E
13	25 Jul–1Aug F (1.9)	11/77	2/4 (5.2)	2/4 (5.2)	5°4′01.84″S, 38°26′13.56″E
1992					
48/1, 71	27 Aug–5 Sep F (control)	11/99	2/5 (5.1)	2/5 (5.1)	5°4′03.22″S, 38°24′40.32″E
49/5, 73	27 Aug–5 Sep F (control)	21/189	2/8 (4.2)	2/8 (4.2)	5°4′02.63″S, 38°24′37.24″E
50	28 Aug–5 Sep F (control)	11/88	1/11 (12.5)	1/11 (12.5)	
51/72	28 Aug–5 Sep F (control)	11/88	1/9 (10.2)	1/9 (10.2)	
52	28 Aug–5 Sep F (control)	11/88	1/8 (9.1)	1/8 (9.1)	
53	31 Aug–5 Sep F (control)	11/55	2/2 (3.6)	2/2 (3.6)	
1993					
71/1, 48	18–23 Jul F (control)	11/55	1/3 (5.5)	1/3 (5.5)	
72/51	18–23 Jul F (control)	11/55	1/6 (10.9)	1/6 (10.9)	
73/5, 49	18–23 Jul F (control)	21/105	2/8 (7.6)	2/8 (7.6)	5°4′02.63″S, 38°24′37.24″E
74	19–23 Jul F (control)	11/44	1/6 (13.6)	1/6 (13.6)	
East Usambaras					
1991					
14/31, 58	5–11 Aug F (control)	11/66	2/4 (6.1)	2/4 (6.1)	5°5′37.28″S, 38°36′54.27″E
1992					
Monga					
16	18–26 Jul T	21/168	4/20 (11.9)	2/10 (6.0)	5°3′47.27″S, 38°36′11.53″E
17	19–24 Jul F (0.6 ha)	11/55	1/5 (9.1)	1/5 (9.1)	5°3′45.47″S, 38°36′10.46″E
18	19–24 Jul F (0.2A ha)	11/55	2/2 (3.6)	2/2 (3.6)	5°3′33.96″S, 38°36′11.72″E
19	19–24 Jul F (3.3 ha)	11/55	3/6 (10.9)	3/6 (10.9)	5°3′47.21″S, 38°36′15.21″E
20	19–24 Jul F (3.3 ha)	11/55	0	0	5°3′44.72″S, 38°36′18.06″E
21	24 Jul–1 Aug F (0.2B ha)	11/88	1/1 (1.1)	1/1 (1.1)	5°3′33.14″S, 38°36′02.66″E
22	24 Jul–1 Aug A (between 0.2B & 0.8 ha)	11/88	1/1 (1.1)	0	5°3′31.96″S, 38°36′02.71″E
23	24 Jul–1 Aug F (0.8 ha)	11/88	0	0	5°3′29.68″S, 38°36′02.98″E
24	24 Jul–1 Aug T	11/88	3/5 (5.7)	2/4 (4.5)	5°3′38.72″S, 38°36′18.27″E
25	24 Jul–1 Aug F (29.4 ha)	11/88	0	0	5°3′27.63″S, 38°36′24.79″E
26	26 Jul–1 Aug F (29.4 ha)	11/66	1/1 (1.5)	1/1 (1.5)	5°3′32.91″S, 38°36′20.85″E
27	26 Jul–1 Aug F (29.4 ha)	11/66	1/3 (4.5)	1/3 (4.5)	5°3′29.50″S, 38°36′22.19″E
NE portion of EU control site					
28	2–8 Aug D (control)	11/66	0	0	5°5′49.01″S, 38°36′56.49″E
29/57	2–8 Aug T	11/66	3/4 (6.1)	2/3 (4.5)	5°5′39.36″S, 38°36′57.38″E
30	2–8 Aug F (control)	11/66	1/1 (1.5)	0	5°5′38.40″S, 38°36′49.29″E
31/14, 58	2–8 Aug F (control)	11/66	4/5 (7.6)	3/3 (4.5)	5°5′37.28″S, 38°36′54.27″E
32	2–8 Aug D (control)	11/66	2/5 (7.6)	1/4 (6.1)	5°5′54.22″S, 38°37′03.17″E
33	2–8 Aug D (control)	11/66	3/5 (7.6)	2/4 (6.1)	5°6′01.47″S, 38°37′03.95″E
Bulwa					
34	8–14 Aug F (2.6 ha)	11/66	1/1 (1.5)	1/1 (1.5)	5°1′33.98″S, 38°36′57.34″E
35	9–14 Aug T	11/55	0	0	5°1′33.39″S, 38°37′02.37″E
36	9–14 Aug F (3.1 ha)	11/55	1/1 (1.8)	1/1 (1.8)	5°1′49.84″S, 38°37′23.38″E
37	9–14 Aug F (0.4 ha)	11/55	1/2 (3.6)	1/2 (3.6)	5°2′02.71″S, 38°36′51.83″E
SW portion of EU control site					
38/65	15–20 Aug F (control)	11/55	1/1 (1.8)	1/1 (1.8)	5°6′18.32″S, 38°35′54.10″E
39/66	15–25 Aug F (control)	11/110	2/2 (1.8)	2/2 (1.8)	5°6′11.49″S, 38°35′58.73″E
40/67	15–25 Aug F (control)	11/110	3/4 (3.6)	2/3 (2.7)	5°6′15.739″S, 38°36′07.67″E
41/68	15–25 Aug F (control)	11/110	3/3 (2.7)	1/1 (0.9)	5°6′22.41″S, 38°36′11.25″E
42	16–25 Aug F (control)	11/99	3/7 (7.1)	3/7 (7.1)	5°6′16.48″S, 38°35′50.25″E

Table 4. *Continued.*

Pitfall line/subsequent lines in same location	Dates and habitat (site)	No. of buckets/ bucket-nights	No. of species/no. of individuals (overall trap success [%])	No. of shrew species/no. of shrews (shrew trap success [%])	Coordinates
43/64	15–20 Aug T	11/55	0	0	5°6′39.52″S, 38°35′40.06″E
44/70	16–21 Aug A	11/55	1/3 (5.5)	1/3 (5.5)	5°6′38.69″S, 38°35′51.30″E
45	20–25 Aug F (control)	11/55	1/1 (1.8)	1/1 (1.8)	5°6′21.29″S, 38°35′59.91″E
46	20–25 Aug F (control)	11/55	2/2 (3.6)	2/2 (3.6)	5°6′24.51″S, 38°36′04.51″E
47	21–25 Aug F (control)	11/44	0	0	5°6′05.01″S, 38°36′03.74″E
1993					
NE portion of EU control site					
57	31 Jul–6 Aug T	11/66	1/1 (1.5)	0	5°5′39.36″S, 38°36′57.38″E
58/14, 31	31 Jul–6 Aug F (control)	11/66	1/4 (6.1)	1/4 (6.1)	5°5′37.28″S, 38°36′54.27″E
59	31 Jul–6 Aug F (control)	11/66	1/4 (6.1)	1/4 (6.1)	5°5′37.73″S, 38°36′37.98″E
60	31 Jul–6 Aug F (control)	11/66	2/5 (7.6)	2/5 (7.6)	5°5′40.48″S, 38°36′40.59″E
61	31 Jul–6 Aug F (control)	11/66	2/2 (3.0)	2/2 (3.0)	5°5′37.78″S, 38°36′32.40″E
62	1–6 Aug F (control)	11/55	2/5 (9.1)	2/5 (9.1)	5°5′42.22″S, 38°36′32.35″E
63	1–6 Aug F (control)	11/55	1/6 (10.9)	1/6 (10.9)	5°5′42.08″S, 38°36′30.96″E
SW portion of EU control site					
64/43	6–13 Aug T	11/77	2/2 (2.6)	1/1 (1.3)	5°6′39.52″S, 38°35′40.06″E
65/38	7–13 Aug F (control)	11/66	2/3 (4.5)	2/3 (4.5)	5°6′18.32″S, 38°35′54.10″E
66/39	7–13 Aug F (control)	11/66	1/3 (4.5)	1/3 (4.5)	5°6′11.49″S, 38°35′58.73″E
67/40	7–13 Aug F (control)	11/66	2/4 (6.1)	2/4 (6.1)	5°6′15.739″S, 38°36′07.67″E
68/41	7–13 Aug F (control)	11/66	2/5 (7.6)	2/5 (7.6)	5°6′22.41″S, 38°36′11.25″E
69	7–13 Aug F (control)	11/66	2/15 (22.7)	2/15 (22.7)	5°6′32.46″S, 38°36′25.25″E
70/44	7–13 Aug A	11/66	3/3 (4.5)	3/3 (4.5)	5°6′38.69″S, 38°35′51.30″E

medium-sized Sherman Traps, 23 × 9.5 × 8 cm. The Museum Specials and Victor Traps were purchased from Woodstream Corporation, Lititz, Pennsylvania; the Sherman Traps from H.B. Sherman Traps Inc., Tallahassee, Florida. These traps were set largely for rodents and placed in terrestrial or arboreal positions, along existing trails, and generally in a straight line (Fig. 8). As we sought to maximize capture success, traps were set at sites deemed likely to be frequented by small mammals, rather than at fixed distances or in a grid system. Hence, distances between consecutive traps varied. These traps were rebaited each late afternoon with freshly fried coconut coated in peanut butter. Additional details on trap techniques are given by Stanley et al. (1998). Trap lines were checked twice per day, in the early morning and mid-afternoon. A "trap-night" refers to one trap in operation for a 24 hr period (0700 to 0700 h). Table 5 lists each trap line with placement details. The term "sample-night" is used in discussion of overall sampling effort (including the number of trap-nights and bucket-nights).

Information regarding the placement of each individual trap was recorded, including trap type, measured distance from forest edge (if applicable), measured distance from consecutive traps, estimated height off the ground, details on microhabitat (i.e., under rock or horizontal on 4 cm-diameter vine), and general local habitat (Table 5). The distances between consecutive traps, often starting at the forest edge, were measured with a 50 m ribbon tape, and these distances were summed to determine the total length of each trap line.

Other Trap Techniques—Tomahawk Live Traps (41 by 14 by 14 mm; Tomahawk Live Trap Co., Tomahawk, WI) were set opportunistically for squirrels, other large rodents, and small carnivores. Mist-nets (five-tiered, 12 m long, ~3 m high) were also set opportunistically for bats. Net-sets included placement over water pools and streams, bisecting trails in the forest, and at sites following the natural passage of bats. Occasionally bats were also recovered by W.D.N. from mist-nets used to survey understory birds.

Specimens

Specimens were prepared as either skins with associated skulls and axial skeletons or fixed in formalin. Standard museum measurements were taken (DeBlase & Martin, 1974): total length (from the tip of the nose to the last caudal vertebra), head and body length (from the tip of the nose to the junction of the tail and the body), tail length (from the junction of the tail and body to the last caudal vertebra), hind foot length (from the ankle to the tip of the longest claw for W.T.S., the ankle to the tip of the longest digit for S.M.G.), ear length (from the notch at the base of the ear to the longest point of the ear), and weight. Cranial measurements were taken by W.T.S. using digital calipers. Adults are defined as animals with fully erupted upper molars and the suture between the basioccipital and basisphenoid bones fused. Tissues including heart, liver, and kidney were frozen in liquid nitrogen. All voucher specimens are deposited in the Field Museum of Natural History (FMNH), Chicago, and the University of Dar es Salaam (UDSM), Dar es Salaam, Tanzania, and the tissue samples are deposited in the FMNH.

Statistical Analyses

We used a one-way ANOVA to test for differences between the external measurements of small mammals collected by

FIG. 8. Two different types of traps used to sample rodents in the forests of the East and West Usambara Mountains. Left, a Sherman Live Trap; right, a Victor Rat Trap. Note the flag hanging from the Victor Rat Trap, which was numbered for reference to individual traps. Photos by W. T. Stanley.

S.M.G. and W.T.S. There were significant differences between measurements made by these different field collectors for total length ($P \leq 0.05$), and hind foot length and ear length ($P \leq 0.001$). The differences between the datasets were not statistically significant ($P > 0.05$) for tail length, head and body length, and weight, although tail length was marginal ($P = 0.07$). These results were expected for hind foot length because W.T.S. included the claw in his measurements and S.M.G. did not. However, the differences between measurements of total length and ear length clearly indicate a difference in the way animals were manipulated and, based on these results and previous studies (Blackwell et al., 2006), we present and analyze separately the external measurements recorded by S.M.G. and W.T.S.

Systematics

We follow the taxonomy presented for shrews by Hutterer (2005); rodents by Holden (2005), Musser and Carleton (2005), Thorington and Hoffman (2005), and Woods and Kilpatrick (2005); elephant shrews by Schlitter (2005); and bats by Hoofer and Van Den Bussche (2003), Miller-Butterworth et al. (2007), Simmons (2005), and Thorn et al. (2007). FMNH catalogue numbers are presented for voucher specimens.

Results

Between 1991 and 1993, 1311 mammals were collected in the East and West Usambara Mountains. These specimens represent 12 species of crocidurine shrew, one macroscelidid elephant shrew (see Stanley et al., this volume), 19 species of bat (see Stanley & Goodman, this volume a), and 14 species of rodent (see Stanley & Goodman, this volume b). When categorized by massif, the East Usambara yielded 11 species of shrew, 17 bats, 13 rodents, and one elephant shrew and the West Usambara, seven species of shrew, 12 bats, 12 rodents, and one elephant shrew.

Most of the small mammal specimens were captured using pitfall and trap devices. A total of 18,563 sample-nights was accrued over the three years of the study, including 11,339 sample-nights (3314 bucket-nights and 8025 trap-nights) in the

TABLE 5. Summary of trap lines installed at different sites in the East and West Usambara Mountains between 1991 and 1993. Trap lines are listed by the name used in the field together with any lines set in the same general trap line location (but not in the same exact trap locations) in other years. Also presented are the dates each trap line was in place and habitat type (F = forest, D = disturbed forest, A = agricultural land, T = tea). Overall trap success includes both rodent and shrew captures. Height of traps set above ground (m) is presented as mean ± SD (range), number of traps, and percentage of total line represented by traps set off the ground. Trap line name is given to aid researchers in interpreting field notes recorded by S.M.G. and W.T.S.

Trap line/subsequent lines in same location	Dates	Habitat	No. of traps/trap-nights	No. of species/no. of individuals (overall trap success[%])	No. of rodent species/no. of rodents (rodent trap success[%])	Length of trap line (m)	Mean distance between traps (m) ± SD (range)	Traps set above ground: Average height (m) ± SD (range)	Traps set above ground: n	Traps set above ground: % of total traps	Name of trap line in field notes of S.M.G. and W.T.S.	Coordinates
West Usambara												
1991												
A/AK	1–10 Jul	F	100/750	5/28 (3.7)	4/26 (3.5)						WU Site 1	5°4′3.45″S, 38°24′42.15″E
B/AL, AR	8–16 Jul	F	100/700	5/63 (9.0)	4/62 (8.9)	535	5.6 ± 4.29 (0.5–26)	1.2 ± 0.74 (0.3–3)	39	39	WU Site 2	5°4′0.45″S, 38°24′37.71″E
C	17–24 Jul	F	100/650	6/37 (5.7)	5/35 (5.4)	586	6.3 ± 8.50 (0.5–63.5)	1.0 ± 0.70 (0.1–2.5)	35	35	40 ha line	5°3′40.1″S, 38°23′1.63″E
D	26–31 Jul	F	31/186	4/12 (6.5)	3/11 (5.9)	87	3.2 ± 3.54 (0.3–18)	1.4 ± 0.69 (0.3–2.5)	14	45	0.8 ha line	5°4′3.54″S, 38°25′49.28″E
E	26–31 Jul	F	29/174	4/5 (2.9)	3/4 (2.3)	98	3.5 ± 3.11 (0.5–12)	1.1 ± 0.57 (0.5–2)	11	38	1.8 ha line	5°3′57.59″S, 38°26′2.73″E
F	25–31 Jul	F	50/350	5/9 (2.6)	5/9 (2.6)	—	—	1.4 ± 0.72 (0.3–3)	22	11	2.4 ha line	5°4′20.41″S, 38°25′44.59″E
G	4–12 Jul	F, A, T	50/400	5/24 (6.0)	5/24 (6.0)	GRID					Grid #1 line	5°3′48.18″S, 38°24′48.95″E
H	5–17 Jul	D	20/240	7/58 (24.2)	6/57 (23.7)						2^0 line #1	5°3′57.84″S, 38°24′37.9″E
I	11–16 Jul	F, A, T	50/250	6/19 (7.6)	6/19 (7.6)						Grid site line	5°3′39.72″S, 38°24′49.55″E
J	13–17 Jul	D	20/80	6/11 (13.8)	4/9 (11.3)						Malte's line	5°3′44.52″S, 38°24′46.15″E
K	19–24 Jul	D	40/200	2/13 (6.5)	2/13 (6.5)						*Maesopsis* line	5°3′37.34″S, 38°23′9.49″E
L	25–31 Jul	A	25/175	2/3 (1.7)	1/2 (1.1)						*Eucalyptus* line	5°4′28.03″S, 38°25′46.83″E
1992												
AK/A	28 Aug–3 Sep	F	90/450	5/58 (12.9)	5/58 (12.9)	548	6.4 ± 6.54 (0.1–36)	1.5 ± 0.74 (0.3–3)	24	27	SMG Control	5°4′3.45″S, 38°24′42.15″E
AL/B, AR	28 Aug–2 Sep	F	91/455[1]	3/52 (11.4)	3/52 (11.4)	322.5	4.8 ± 2.85 (0.3–12.6)	1.4 ± 0.50 (0.35–2.5)	26	37	WTS Control[1]	5°4′0.45″S, 38°24′37.71″E
1993												
AR/B, AL	19–23 Aug	F	60/240	5/29 (12.1)	5/29 (12.1)	325	5.5 ± 3.64 (0.5–15.5)	1.4 ± 0.38 (1–2.5)	22	37	WU Control 1993	5°4′0.45″S, 38°24′37.71″E
East Usambara												
1991												
NE portion of EU control site												
M/X, AM	5–10 Aug	F	50/250	3/11 (4.4)	3/11 (4.4)	199	4.3 ± 3.27 (0.5–13)	1.1 ± 0.68 (0.3–2.5)	18	9	Monga line 1991	5°5′36.49″S, 38°36′52.36″E
N	6–10 Aug	F, D	40/160	3/7 (4.4)	3/7 (4.4)	—	—	1.3 ± 0.53 (0.5–2)	16	40	Ecotone line	5°5′29.68″S, 38°36′56.38″E

Table 5. *Continued.*

Trap line/subsequent lines in same location	Dates	Habitat	No. of traps/trap-nights	No. of species/no. of individuals (overall trap success[%])	No. of rodent species/no. of rodents (rodent trap success[%])	Length of trap line (m)	Mean distance between traps (m) ± SD (range)	Traps set above ground: Average height (m) ± SD (range)	Traps set above ground: n	Traps set above ground: % of total traps	Name of trap line in field notes of S.M.G. and W.T.S.	Coordinates
1992												
Monga												
O	19–24 Jul	F	30/150	3/9 (6.0)	3/9 (6.0)	40	2.3 ± 2.07 (0.5–10)	1.4 ± 0.55 (0.5–2.5)	10	33	0.1 ha line	5°3′33.78″S, 38°36′12.7″E
P	20–25 Jul	F	47/235	2/9 (3.8)	2/9 (3.8)	—	—	1.4 ± 0.85 (0.5–4)	16	34	9.4 ha A	5°3′47.69″S, 38°36′14.38″E
Q	20–25 Jul	F	45/225	2/9 (4.0)	2/9 (4.0)	—	—	1.5 ± 0.79 (.25–3)	12	27	9.4 ha B	5°3′47.69″S, 38°36′14.38″E
R	19–24 Jul	F	74/370	4/19 (5.1)	3/18 (4.9)	—	—	1.2 ± 0.75 (0.15–3)	37	50	0.45 ha line	5°3′43.75″S, 38°36′10.23″E
S	25–30 Jul	F	30/150	3/8 (5.3)	3/8 (5.3)	—	—	1.3 ± 0.67 (0.2–3)	15	50	0.42 ha line	5°3′28.63″S, 38°36′3.03″E
T	24–30 Jul	F	60/300	4/22 (7.3)	4/22 (7.3)	—	—	1.3 ± 0.68 (0.1–3)	25	42	0.8 ha line	5°3′34.3″S, 38°36′3.18″E
U	25–30 Jul	F	90/450	5/21 (4.7)	4/20 (4.4)	219	3.0 ± 3.79 (0.25–19)	1.4 ± 0.95 (0.25–4)	26	29	30 ha line	5°3′25.34″S, 38°36′18.1″E
V	24–31 Jul	M	30/210	1/1 (0.5)	1/1 (0.5)						Monga Tea Line	5°3′42.65″S, 38°36′21.04″E
W	29–31 Jul	A	50/140	3/4 (2.8)	1/2 (1.4)						Reservoir line	5°3′55.32″S, 38°36′26.38″E
NE portion of EU control site												
X/M, AM	1–7 Aug	F	70/385	4/25 (6.5)	3/24 (6.2)	221	3.5 ± 3.21 (0.5–14)	1.3 ± 0.56 (0.5–2.5)	28	40	Peninsula line	5°5′35.27″S, 38°36′50.54″E
Y	1–7 Aug	D	30/180	2/19 (10.6)	2/19 (10.6)	139	5.0 ± 1.72 (1.5–8.3)	1.0 ± 0.65 (0.2–2)	14	47	*Maesopsis* A	5°5′41.19″S, 38°37′7.32″E
Z	1–7 Aug	D	60/340	3/42 (12.4)	3/42 (12.4)	358	6.2 ± 2.49 (0.5–13)	1.2 ± 0.69 (0.1–2)	16	27	*Maesopsis* B	5°5′41.19″S, 38°37′7.32″E
Bulwa												
AA	9–13 Aug	F	40/200	3/8 (4.0)	3/8 (4.0)	—	—	1.3 ± 0.49 (0.5–2.5)	15	37	1.6 ha line	5°1′45.58″S, 38°37′27.49″E
AB	9–13 Aug	F	15/75	1/3 (5.0)	1/3 (5.0)	35.8	2.6 ± 1.58 (0.8–7.5)	1.3 ± 0.54 (0.8–2)	4	27	0.38 ha line	5°2′10.82″S, 38°36′48.38″E
AC	8–13 Aug	F	30/150	2/3 (2.0)	2/3 (2.0)	119	4.0 ± 1.97 (0.5–8.2)	1.2 ± 0.65 (0.2–2.2)	13	43	2.7 ha line	5°1′37.78″S, 38°37′2.39″E
AD	9–13 Aug	T	25/125	1/4 (3.2)	1/4 (3.2)						Bulwa Tea line	5°1′38.83″S, 38°36′58.23″E
AE	9–13 Aug	T	30/150	0/0 (0)	0/0 (0)						Bulwa Road line	5°1′37.59″S, 38°36′59.63″E
SW portion EU control site												
AF/AQ	14–20 Aug	F	62/372	6/21 (5.6)	6/21 (5.6)	191	3.6 ± 3.53 (0.25–18)	1.3 ± 0.72 (0.25–2.5)	21	34	Netline A	5°6′21.43″S, 38°35′52.07″E
AG/AP	14–20 Aug	F	100/600	5/36 (6.0)	4/35 (5.8)	627	5.5 ± 2.31 (0.2–11)	1.4 ± 0.56 (0.3–2)	34	42	Netline B[1]	5°6′21.43″S, 38°35′52.07″E
AH/AP	20–26 Aug	F	100/500[1]	4/40 (8.0)	4/40 (8.0)	226	4.2 ± 3.19 (0.1–11)	1.3 ± 0.62 (0.2–2.5)	29	48	Netline B2[1]	5°6′21.43″S, 38°35′52.07″E
AI	20–25 Aug	F	62/310	2/17 (5.5)	2/17 (5.5)	—	—	1.2 ± 0.54 (0.25–2.5)	21	34	Ridge line	5°6′31.01″S, 38°36′6.52″E

Table 5. *Continued.*

Trap line/subsequent lines in same location	Dates	Habitat	No. of traps/trap-nights	No. of species/no. of individuals (overall trap success[%])	No. of rodent species/no. of rodents (rodent trap success[%])	Length of trap line (m)	Mean distance between traps (m) ± SD (range)	Traps set above ground: Average height (m) ± SD (range)	Traps set above ground: n	Traps set above ground: % of total traps	Name of trap line in field notes of S.M.G. and W.T.S.	Coordinates
AJ	19–24 Aug	D	30/150	2/12 (8.0)	2/12 (8.0)	179	6.0 ± 3.58 (0.5–11)	1.2 ± 0.75 (0.25–2)	8	27	*Maesopsis* C	5°6′28.95″S, 38°35′53.59″E
AS	14–19 Aug	T	30/150	0/0 (0)	0/0 (0)	—	—				Kwomkoro Tea line	
1993												
NE portion of EU control site												
AM/M, X	31 Jul–5 Aug	F	50/250	2/5 (2.0)	2/5 (2.0)	159	3.4 ± 2.82 (0.5–10)	1.6 ± 0.51 (1–2.5)	17	8.5	Peninsula	5°5′35.00″S, 38°36′50.35″E
AN	31 Jul–6 Aug	F	50/250	3/20 (8.0)	3/20 (8.0)	—	—	1.0 ± 0.58 (0.15–2)	16	8	Near Peninsula	5°5′31.96″S, 38°36′48.32″E
AO	31 Jul–6 Aug	F	100/500[1]	5/20 (4.0)	3/16 (3.2)	424	8.5 ± 3.95 (1–20)	1.5 ± 0.59 (0.6–3)	18	9	Road control 1993 A[1]	5°5′49.22″S, 38°36′49.87″E
AP/AG, AH	7–14 Aug	F	50/350[1]	6/22 (6.3)	5/21 (6.0)	513	7.7 ± 5.45 (1–20.5)	1.5 ± 0.38 (1–2)	8	27	Turaco–Bill's[1]	5°6′21.43″S, 38°35′52.07″E
AQ/AF	7–14 Aug	F	50/348	4/22 (6.3)	4/22 (6.3)	216	4.5 ± 4.08 (0.5–15)	1.2 ± 0.59 (0.25–2)	18	9	Turaco–Steve's	5°6′21.43″S, 38°35′52.07″E

[1] Metrics were based on a subset of the trap line: AG, first 80 traps; AH, first 70 traps; AL, first 71 traps; AO line, first 30 traps; AP line, last 50 traps; AQ, first 30 traps.

East Usambara and 7224 (1924 bucket-nights and 5300 trap-nights) in the West Usambara. Details of trapping effort by massif, habitat, and year are presented in Tables 2 and 3.

Trap and pitfall lines alone (excluding incidental captures by hand or specimens brought to us by local residents; see below) resulted in the capture of 1132 animals, representing 11 species of crocidurine shrew and 13 species of rodent. These two trapping methodologies yielded 10 species of shrew and 12 species of rodent in the East Usambara, and six species of shrew and 10 species of rodent in the West Usambara. The vast majority of shrews captured (91.2%) were taken in pitfall buckets; only 23 of the 263 shrews collected were taken in traps or by hand. These results are consistent with other studies of small mammals in montane regions of Tanzania (Stanley et al., 1996). In most cases, shrews obtained in traps were represented more commonly in the pitfall captures. The exception is our single specimen of *Crocidura jacksoni* collected in a Museum Special. Conversely, most rodents collected (96.6%) were taken in traps, and relatively few in pitfall buckets. However, all specimens of the rodent genus *Dendromus* (n = 11) were obtained in pitfalls.

An additional 179 mammals were collected in mist-nets, traps installed by local people, or by hand. These include single individuals of a shrew (*C. elgonius* found dead on the road) and *Petrodromus* and *Rhynchocyon* elephant shrews (see Stanley et al., this volume), 161 bats representing 19 species (see Stanley & Goodman, this volume a), and 16 rodents (nine *Heliophobius argenteocinereus*, three *Paraxerus vexillarius*, three *Lophuromys aquilus*, and one *Praomys delectorum*; see Stanley & Goodman, this volume b).

Species Accumulation Curves within and between Seasons

As previously demonstrated (Stanley et al., 1996, 1998), trap and pitfall lines combined are an effective way to sample most shrews and small to medium-sized rodents of an area. However, the duration such trapping is needed to document the fauna of an area is still unresolved. Other surveys using similar techniques in other areas of tropical Africa show different patterns. For example, extensive insectivore surveys conducted on Monts Doudou in Gabon at 110 m elevation by Goodman and Hutterer (2004) and Nicolas et al. (2004) took place a few hundred meters apart. In the first study, nine species of shrews were trapped in 264 bucket-nights, and in the second study the same species were found after 8820 bucket-nights. Hence, in this case, the number of known taxa at a relatively species-rich site plateaued in eight days of trapping with 33 installed pitfall buckets (264 accrued bucket-nights).

During a two-year study, Stanley et al. (1998) found a previously unrecorded rodent species (*Graphiurus murinus*) in the Chome Forest Reserve, South Pare Mountains, in trap lines only during the last of 22 days of sampling, after 3794 accrued trap-nights. In the East Usambara Mountains, species captured for the first time late in the study included *Crocidura usambarae,* after 3160 bucket-nights and *G. kelleni,* after 7827 trap-nights. Our trapping efforts in the East Usambara, during three years of fieldwork, did not yield an extended plateau in the species accumulation curve; two species were added to the cumulative number of species recorded in this zone during the third year, after more than 10,000 sample-nights (Figs. 9 and 10). Longer survey efforts, both within a season and across years, may be necessary to document comprehensively the small mammal fauna in the montane forests of this massif.

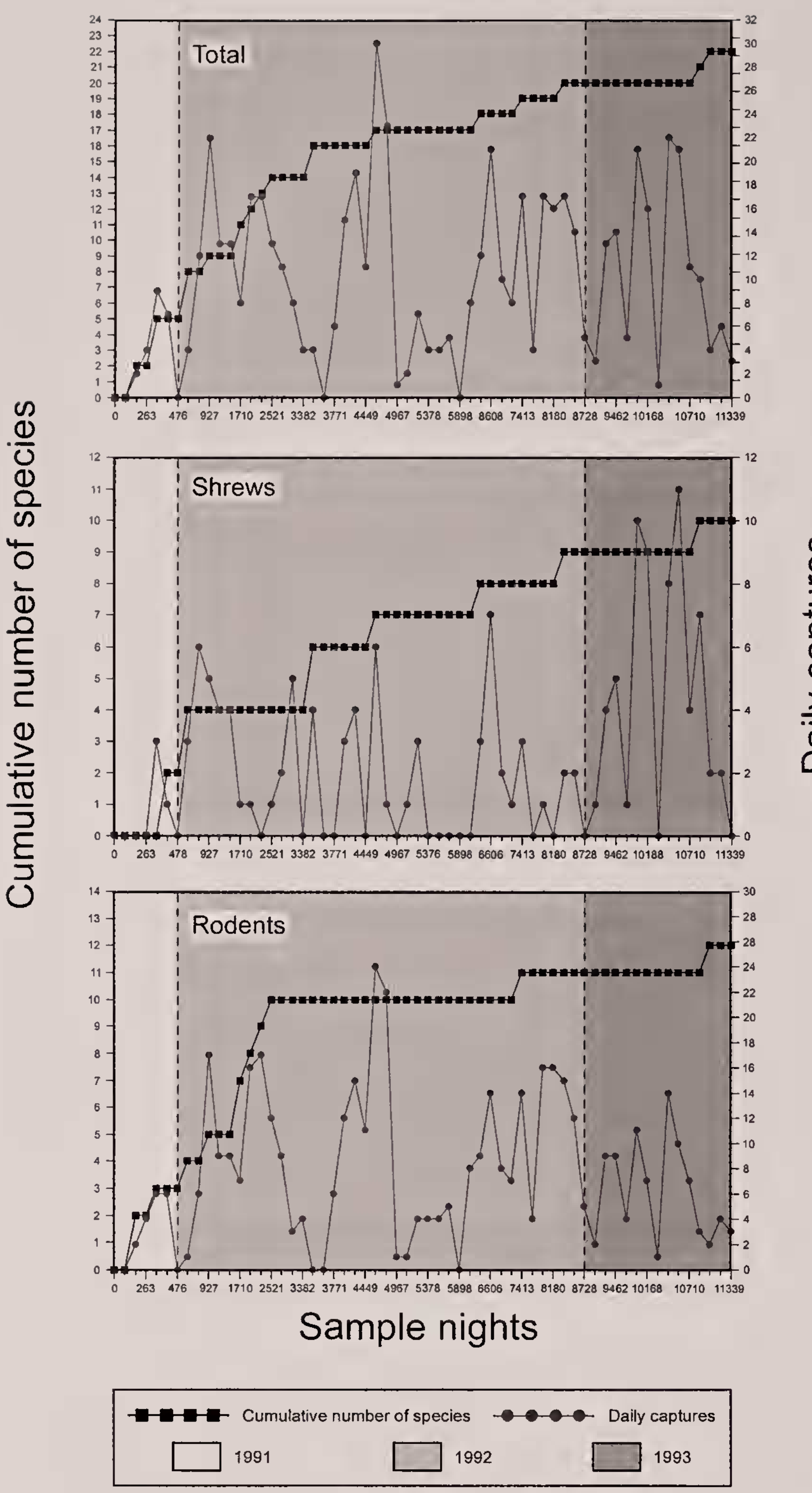

FIG. 9. East Usambara species accumulation curves showing both daily captures and cumulative number of species plotted vs. cumulative number of sample-nights. Each of the three years of the study is shaded differently.

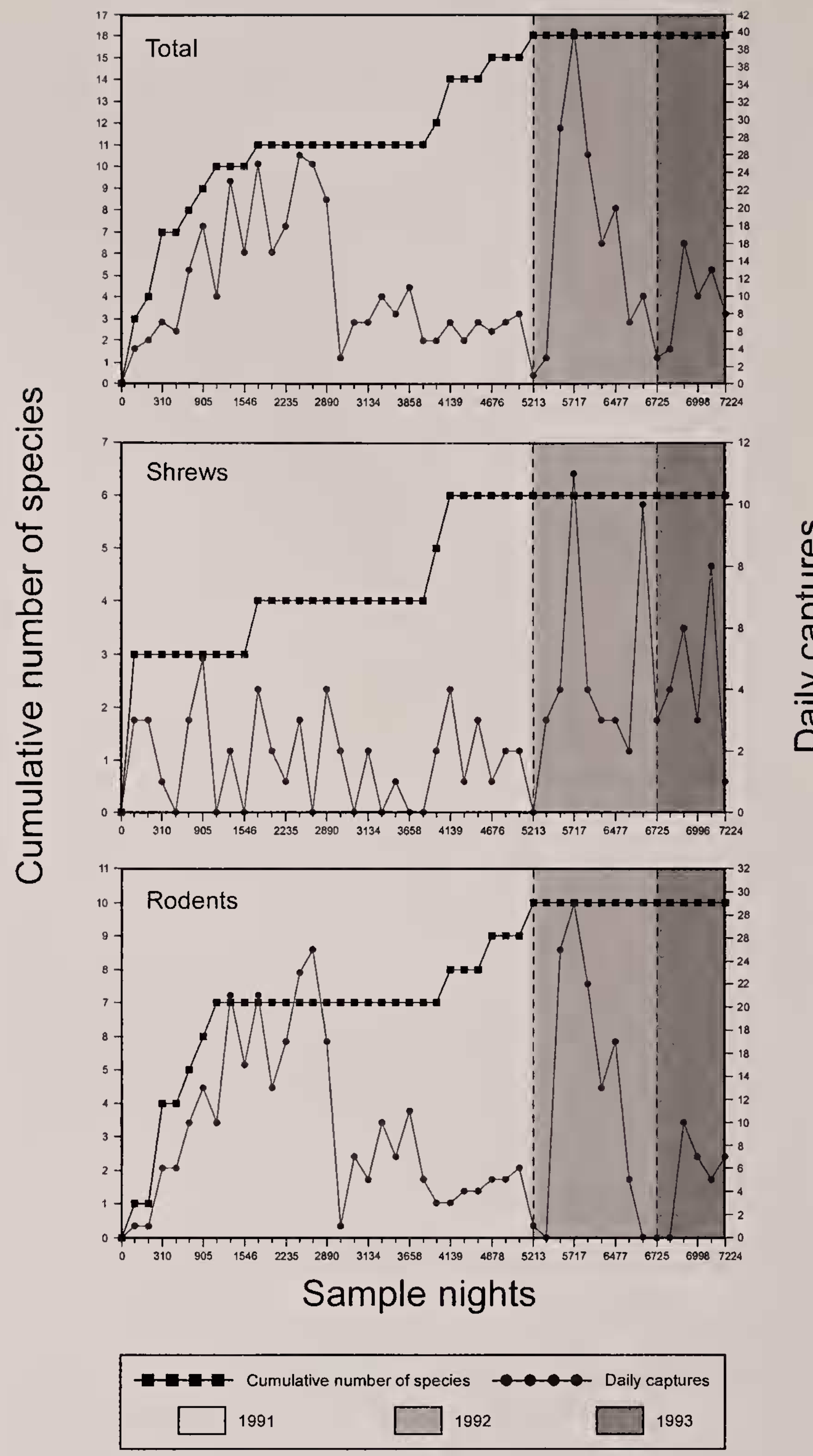

FIG. 10. West Usambara species accumulation curves showing both daily captures and cumulative number of species plotted vs. cumulative number of sample-nights. Each of the three years of the study is shaded differently.

Some of the species documented during our surveys could have been recent immigrants into the sampled habitats, either colonizing the zone naturally from lower elevations or, perhaps, even introduced by human intervention. We emphasize that patterns of species occurrence in a given forest block are not static, but dynamic. For example, based on inventory data, the resident and migratory bird fauna that the Moreaus (Moreau, 1935, 1937; Moreau & Moreau, 1937) knew in the East Usambara in the 1930s differs from that in this zone today (Stuart, 1983; Cordeiro, 1998b; Seddon et al., 1999). These aspects, overlaid on the effects of climatic change, need to be considered in future studies of the Usambara fauna.

Variation in Species Richness and Capture Rates between Seasons

Some trap and pitfall lines were placed in the same positions over two or three consecutive years of the study. In general, the pitfall buckets were placed in the same holes excavated the previous year. Although we did not place individual traps in the same exact location each consecutive year, repeated lines commenced at the same place and followed the general trail of the previous year. This replication allowed us to assess variation in abundance and diversity across the years sampled.

Figure 11 shows the results of three years of three consecutive pitfall lines (one in the East and two in the West Usambara), and two trap lines (one in each mountain range) installed in the same exact (pitfall) or general (trap) locations all three years. While abundance (based on pitfall or trap success) varied from year to year, abundance did not decrease; our removal sampling therefore did not measurably affect the abundance of shrews and rodents in the immediate area. We statistically tested this observed pattern with a one-way analysis of variance. Pitfall and trap lines in each range and year were standardized by analyzing the results of the first 11 buckets and first 35 traps of each line during the first four days the line was in operation. We found no significant difference in either the total number of individuals captured (i.e., trap success; pitfall lines: $F_{2,6} = 2.19$, $P = .19$; trap lines: $F_{2,3} = 0.16$, $P = 0.86$) or in the total number of species

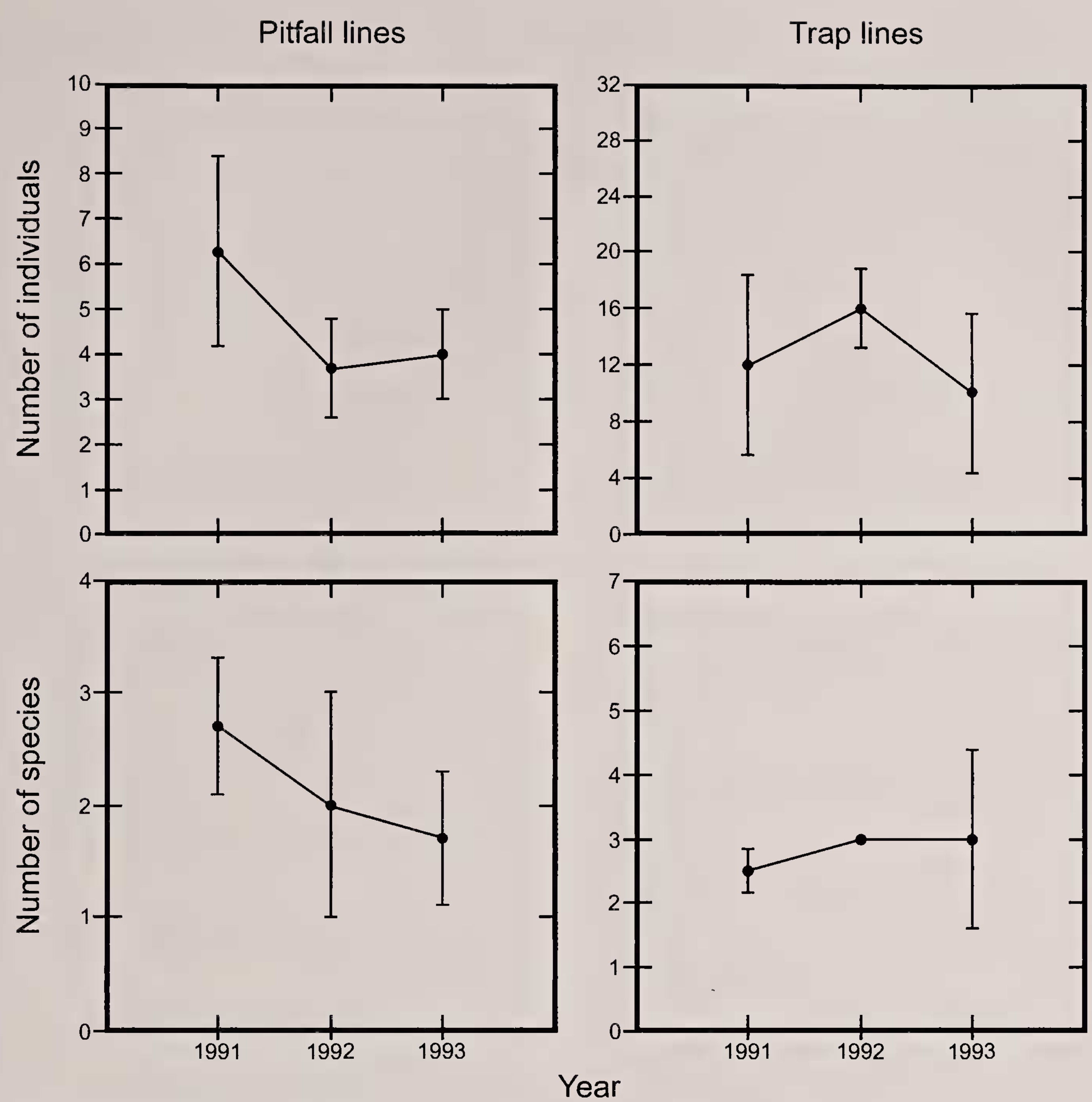

FIG. 11. Means and standard deviations of number of individuals (**top**) and species (**bottom**) captured in three pitfall lines (**left**) and two trap lines (**right**) operated over three consecutive years at the same locations in the EU and WU control sites.

captured (i.e., diversity; pitfall lines: $F_{2,6} = 1.40$, $P = 0.32$; trap lines: $F_{2,3} = 2.68$, $P = 0.21$) among the three years of the study.

Concluding Remarks

The survey data presented here and in Stanley et al. (this volume) and Stanley and Goodman (this volume a,b) highlight the mammalian diversity of the East and West Usambara Mountains. Our measures of species richness of these two massifs will almost certainly increase as new areas, at different elevations or with different habitats, are surveyed. Furthermore, on-going systematic studies using morphological and molecular genetic characters will provide insight into previously unrecognized cryptic species. These two massifs hold a rich assemblage of small mammals, with local and regional endemics, and should be the subject of continued and bolstered research and conservation activities.

Acknowledgments

We thank the Commission of Science and Technology for permission to carry out this study. The study was supported by the National Geographic Society (grants 5053-93, 5244-94, 5711-96), the Marshall Field Fund and the Ellen Thorne Smith Fund of The Field Museum of Natural History, and the Chicago Zoological Society. The taxonomic studies of Rainer Hutterer at the Field Museum of Natural History were supported by the Robert O. Bass Fund of that same institution. Maiko Munissi, Jermiah Peters, and Charles Challanga helped in the field. Budda Acharya of the Monga Tea Estate was a kind host. Kim M. Howell was incredibly helpful and supportive during this study and offered helpful comments on earlier drafts. Don Wilson and Christian Denys provided useful advice on various chapters in this volume. Rebecca Banasiak, Alison Ebert, Joanne Kozuchowski, Sarah Lansing, and Mary Anne Rogers all helped in the preparation of the manuscript. Finally, Janet Voight offered constructive comments throughout the preparation of this volume.

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